LAB 7

Lab Handout

Lab 7. Forces on an Incline: What Is the Mathematical Relationship Between the Angle of Incline and the Acceleration of an Object Down the Incline?

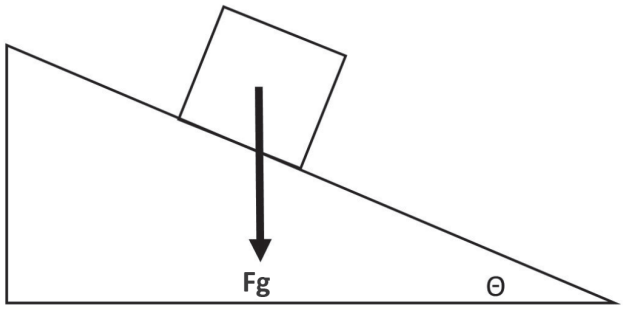
Introduction

Physicists have been studying the motion of objects on an incline for centuries because most of the world is not flat. This line of research is important because many people live on or near hills or mountains and must build homes, store equipment, and travel from one location to another on an incline. Engineering of large structures has required further study of how objects do or do not move down an incline. For example, when building parking garages, many engineers build garages so that cars can be parked on the incline of the garage between levels, and not just on the flat surface.

Scientists often use Newton's laws of motion to understand the relationship between the net force exerted on an object on an incline plane, its inertial mass, and its acceleration. Acceleration is equal to the rate of change of velocity with respect to time, and velocity is equal to the rate of change of position with respect to time. Gravity is one of the forces that act on an object on an incline plane. The force of gravity pulls the object toward the center of the Earth. This is important to keep in mind because it means that gravity does not act directly down the incline. Figure L7.1 shows how the force of gravity (**Fg**) acts on a box sitting on a ramp. It also shows how scientists measure the angle of incline. As can be seen in this figure, the angle of incline (θ) is measured relative to a flat, horizontal surface (as opposed to measuring the angle from the vertical). Therefore, when the measure of the angle is 0°, the surface is flat. When the angle of incline is 90°, it is a vertical surface and an object no longer moves down the surface, but instead moves in free fall.

FIGURE L7.1

A force diagram for an object on an incline plane



As mentioned above, it is important for us to understand how the angle of an incline plane affects the motion of an object on the incline for many different reasons. An engineer who is responsible for designing and building a parking garage, for example, needs to

understand how the angle of incline in the garage will affect the motion of parked cars because if he or she makes the incline in the garage too steep, then the cars may roll or slide down the incline, even when they are in park. When this happens, property can be damaged and people can get hurt. In this investigation, you will have an opportunity to learn more about the relationship between the angle of an incline and the motion of object on that incline.

Your Task

Use what you know about forces and motion, the importance of looking for patterns, and the relationship between structure and function to design and carry out an investigation to examine how a toy car moves down the incline. The goal of this investigation is to come up with an equation that you can use to predict the acceleration of the toy car down as it moves down an incline.

The guiding question of this investigation is, ***What is the mathematical relationship between the angle of incline and the acceleration of an object down the incline?***

Materials

You may use any of the following materials during your investigation:

Consumables
- Tape
- String or fishing line

Equipment
- Safety glasses or goggles (required)
- Plastic cup
- Small toy car or cart
- Electronic or triple beam balance
- Small masses
- Meterstick
- Protractor
- Ramp or board
- Stopwatch
- Pulley

If you have access to the following equipment, you may also consider using a video camera and a computer or tablet with video analysis software.

Safety Precautions

Follow all normal lab safety rules. In addition, take the following safety precautions:

1. Wear sanitized safety glasses or goggles during lab setup, hands-on activity, and takedown.
2. Keep fingers and toes out of the way of moving objects.
3. Do not stand on tables and chairs.
4. Wash hands with soap and water after completing the lab.

LAB 7

Investigation Proposal Required? ☐ Yes ☐ No

Getting Started

To answer the guiding question, you will need to design and carry out an experiment. To accomplish this task, you must determine what type of data you need to collect, how you will collect it, and how you will analyze it.

To determine *what type of data you need to collect,* think about the following questions:

- What are the boundaries and components of the system you are studying?
- How do the components of the system interact with each other?
- Which factors might control the rate of change in velocity of the toy car?
- How might a change in the structure of the incline affect how the moving object functions?
- How could you keep track of changes in this system quantitatively?
- What forces are acting on the toy car when it is on the incline?
- What information will you need to be able to determine the acceleration of the toy car?
- What will be the independent variable and the dependent variable for your experiment?

To determine *how you will collect the data,* think about the following questions:

- How will you change the independent variable during your experiment?
- What other factors will you need to hold constant during your experiment?
- How will you measure the magnitude and direction of any vector quantities?
- What equipment will you need to collect the data?
- How will you make sure that your data are of high quality (i.e., how will you reduce error)?
- How will you keep track of and organize the data you collect?

To determine *how you will analyze the data,* think about the following questions:

- What types of patterns might you look for as you analyze your data?
- How could you use mathematics to describe a relationship between variables?
- What type of calculations will you need to make?
- What types of graphs and equations signify a proportional relationship?
- What type of table or graph could you create to help make sense of your data?

Connections to the Nature of Scientific Knowledge and Scientific Inquiry

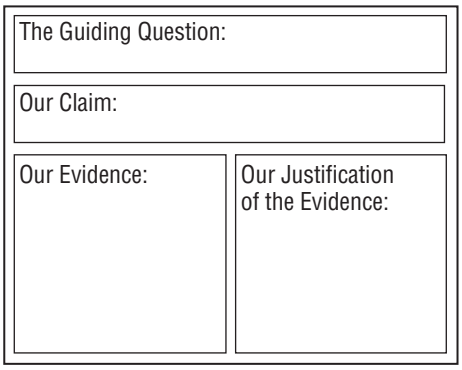
As you work through your investigation, you may want to consider

- the difference between observations and inferences in science, and
- how scientists use different methods to answer different types of questions.

Initial Argument

Once your group has finished collecting and analyzing your data, your group will need to develop an initial argument. Your initial argument needs to include a claim, evidence to support your claim, and a justification of the evidence. The *claim* is your group's answer to the guiding question. The *evidence* is an analysis and interpretation of your data. Finally, the *justification* of the evidence is why your group thinks the evidence matters. The justification of the evidence is important because scientists can use different kinds of evidence to support their claims. Your group will create your initial argument on a whiteboard. Your whiteboard should include all the information shown in Figure L7.2.

FIGURE L7.2
Argument presentation on a whiteboard



Argumentation Session

The argumentation session allows all of the groups to share their arguments. One or two members of each group will stay at the lab station to share that group's argument, while the other members of the group go to the other lab stations to listen to and critique the other arguments. This is similar to what scientists do when they propose, support, evaluate, and refine new ideas during a poster session at a conference. If you are presenting your group's argument, your goal is to share your ideas and answer questions. You should also keep a record of the critiques and suggestions made by your classmates so you can use this feedback to make your initial argument stronger. You can keep track of specific critiques and suggestions for improvement that your classmates mention in the space below.

Critiques about our initial argument and suggestions for improvement:

If you are critiquing your classmates' arguments, your goal is to look for mistakes in their arguments and offer suggestions for improvement so these mistakes can be fixed. You should look for ways to make your initial argument stronger by looking for things that the other groups did well. You can keep track of interesting ideas that you see and hear during the argumentation in the space below. You can also use this space to keep track of any questions that you will need to discuss with your team.

Interesting ideas from other groups or questions to take back to my group:

Once the argumentation session is complete, you will have a chance to meet with your group and revise your initial argument. Your group might need to gather more data or design a way to test one or more alternative claims as part of this process. Remember, your goal at this stage of the investigation is to develop the best argument possible.

Report

Once you have completed your research, you will need to prepare an investigation report that consists of three sections. Each section should provide an answer to the following questions:

1. What question were you trying to answer and why?
2. What did you do to answer your question and why?
3. What is your argument?

Your report should answer these questions in two pages or less. This report must be typed, and any diagrams, figures, or tables should be embedded into the document. Be sure to write in a persuasive style; you are trying to convince others that your claim is acceptable or valid!

Checkout Questions

Lab 7. Forces on an Incline: What Is the Mathematical Relationship Between the Angle of Incline and the Acceleration of an Object Down the Incline?

1. Draw a free-body diagram of the forces acting on a toy car accelerating down an incline.

2. In your investigation, you determined the relationship between the angle of incline and the acceleration of a toy car moving down the incline. Assuming there is no friction between the incline and the object that is placed on it, would your equation change if the mass of the object were increased?

   a. Yes
   b. No

   Explain your answer.

3. The wheels on the toy car reduced the impact of the force of friction on the motion of the toy car as it traveled down the incline. What would your data have looked like if the frictional force acting on the incline were larger? Use data from your investigation as part of your answer.

4. Scientists can make different inferences from the same observations.

    a. I agree with this statement.
    b. I disagree with this statement.

    Explain your answer, using an example from your investigation about objects moving down an incline.

5. There is a scientific method that all scientists must follow.

    a. I agree with this statement.
    b. I disagree with this statement.

    Explain your answer, using an example from your investigation about objects moving down an incline.

6. Why is important to look for patterns in science? In your answer, be sure to include examples from at least two different investigations.

7. Why is important to think about the relationship between structure and function in nature during an investigation? In your answer, be sure to include examples from at least two different investigations.